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and Trematis, in *Amer. Geol.* for June; and in the same journal for April, Preliminary Description of New Lower Silurian Sponges.

Warren Upham mentions some Marine Shells and Fragments of Shells in the Till near Boston, in *American Journal of Science*, May number.

AUTOTOMY IN THE CRAB.

BY E. A. ANDREWS.

THAT crabs when roughly handled may throw off one or more legs at a point close to the body, is a fact well-known and often observed.

As little bleeding takes place in such cases, and as the crab may thus escape complete destruction, and is able to grow new legs, this power of self-amputation is of evident advantage to the species, and might at first sight be regarded as an intelligent act consciously performed by the crab under certain circumstances.

The experimental work of Léon Fredericq has, however, demonstrated that such amputations are merely reflex acts brought about by special mechanisms, and may be included with similar phenomena in other animals under the term " Autotomy."

From the various publications upon this subject we may abstract the chief facts relating to the crab, as given by the above author in his *Travaux du Laboratoire*, I.-II., 1887–8.

He there shows that this rupture of the limbs is not due to fragility, since the weight necessary to break off a limb is many times that of the crab's body, and the rupture thus produced is an irregular one, taking place generally at some joint of the limb, and not at the normal " plane of rupture."

That, moreover, this autotomy is not a voluntary act was shown as follows: A crab when fastened by one or more legs endeavors to escape, but does not hit upon the expedient of throwing off a fastened leg, though if even a free leg is seriously injured, the crab then amputates it. When the brain (supraœsophageal ganglion) is removed, the self-amputation may still be brought about: the same result follows when the brain is thrown out of the experiment by anæsthetizing the animal with ether or chloroform.

Peripheral stimuli may be applied to the limb in various ways in order to bring about autotomy; thus crushing or cutting the segments of the leg (unless it be the terminal ones) is very soon followed by the falling off of the leg at a definite point near the body, while alcohol, etc., heat, or electric shocks applied to the limb produce the same result. In the latter case the time between the application of the shock and the resulting autotomy was measured and found to vary much.

The centre for the reflex throwing off of the legs is in the thoracic ganglion mass, since the removal of this mass destroys the autotomy, and since in one case electric stimuli applied to this mass brought about the ordinary autotomy!

Concerning the mechanisms by which the impulse going out from this centre is able to bring about the remarkable rupture of the limb at a definite place, the author points out the existence of a special groove around the limb of the crab, on the second segment from the body, and that this segment is moved in two directions by two muscles, raised upward by an extensor and brought downward by a flexor muscle. These two muscles are attached to the upper and lower borders of the second segment at the end towards the first, and pass into the first. When autotomy takes place the limb separates by a clear-cut plane passing across the second segment through the above groove; the stump or first segment, with a small ring from the second, is now held forcibly in an elevated position. Experiment shows that the flexor may be cut without destroying the power of autotomy, while when the extensor is cut autotomy does not take place.

The action of the extensor muscle in autotomy, the author explains as follows, with the use of the diagram reproduced in Fig. 1. The stimulus coming from the leg to the thoracic centre results in the sending out of stimuli to the muscles of the leg, the strong contraction of the extensor (*ex*) brings the leg forcibly against the carapace (*c*) or the fingers of the experimenter, etc., till the reaction produces strain enough to rupture the second segment (*s*) at the groove or weakest point (*a*).

Some observations made upon the region where autotomy takes place, or plane of rupture as we may call it, seem of interest in supplementing the above account from an anatomical point of view. In the crab Libinia the chitinous wall of the limbs is exceeding thick and strong, so that to break it at all —and it will not break with a clear-cut fracture—considerable force is required, so that it seemed to me quite puzzling that the crab could throw off its legs with a smooth, clear-cut fracture, and this by the application of some force acting inside a firm cylinder.

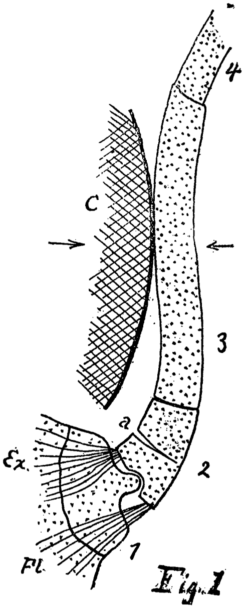

Fig. 1

Experiments made were confirmatory of the facts demonstrated by Léon Fredericq—that autotomy is a reflex act, and that apparently and *probably* it is brought about by muscular contraction forcing the limb against the thorax.

Examination of the second segment shows these two grooves around it (*p* and *d*, Fig. 2) differing in appearance, but both conspicuous from the absence of hairs and hair pores in the exoskeleton along these lines. When autotomy takes place the limb separates along the proximal line (*p*), and the exposed edges of the exoskeleton are smooth and sharp cut. The exposed surface of the soft central part of the limb is covered by a firm membrane except at the centre, where there is a rounded hole with a little torn tissue and blood exposed. After a time a chitinous layer appears over the end of the stump or short ring remaining as representative of the second segment. Though artificial rupture cannot ordinarily be brought about at this "plane of rupture," yet when the limb is

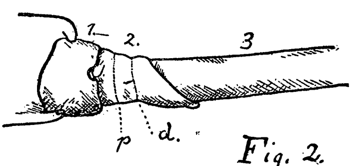

Fig. 2.

decalcified in Perenyi's fluid, it readily separates there just as in autotomy.

Sections of this region of the second segment show that the exoskeleton presents a definite plane of discontinuity in the lamellar structure at the proximal groove (*p*, Fig. 2), this plane being at right angles to the length of the limb, but bending abruptly in the outer part of the exoskeleton, so that after autotomy the exoskeleton of the stump of the limb is somewhat rounded off at its outer edge (*x*, Fig. 3.) This plane of discontinuity is quite different from the pores that penetrate the exoskeleton, and connect with the peculiar scale-like " hairs " (*h*, Fig. 3.) Extending from this exoskeleton part of the "plane of rupture," there is a definite structure in the soft part of the limb forming a double annular curtain (*p*, *r*, Fig. 4), extending inward from the epidermis to the central nerve and blood vessels (*n* and *b*), and thus dividing the cavity of the second segment into a proximal and a distal part,—nearly separated from one another. This curtain is a membranous structure of which the distal part is more delicate, the proximal stouter and of a double nature. This proximal membrane is seen on section to remain upon the stump of the leg, as the conspicuous membrane mentioned above, after normal autotomy.

There is thus a definite " plane of rupture," or preformed mechanism consisting of a modification (*x*) in the exoskeleton (*ex*), and of a membranous ingrowth (*p*, *r*), which together account for the peculiar surface presented after autotomy takes place.

The explanation of the gradual acquisition by the crabs of this highly complex and perfected form of autotomy by natural selection presents difficulties which may, I judge, be lessened if we can show reasons for supposing that the mechanisms involved have their homologues in other animals, and have risen to their perfect expression in the crabs in connection with *change of function.*

Leon Fredericq has shown that the chelæ are thrown off easily, by autotomy, in the craw-fish, while the other legs are either thrown off with difficulty, in the lobster, or not at all, in his experiments on the crayfish. Examinations of these limbs showed that (as easily can be verified) the chelæ have, as in the crab, a groove on the second segment, while the other legs present a free joint at the corresponding point, making thus two segments in place of one, or seven in all in place of six in the chelæ.

Considering the relations of the crab to the Macrurans, there seems no doubt that the second segment in the leg of the former represents the fused second and third segments in the latter; the "plane of rupture" corresponds in position with the free joint between the second and third segments of the leg in the lobster or crayfish.

The appearances seen on sectioning this plane, may, I judge, be explained as a modification of a former free joint; the double membrane and line of discontinuity of exoskeleton representing the invagination of body-wall seen at an ordinary movable joint where tendons for attachment of muscles are formed.

As the lobster appears to have the power, though feebly developed, of throwing off the legs at the free joint between the second and third segments, and as this power is better developed in the chelæ, where fusion of the above segments has taken place, may we not suppose that the more perfect and ready autotomy in the crab has been gradually derived from the former conditions as a "change of functions" took place from a movable joint to a definite "plane of rupture"?

That this "plane of rupture" is found in the Megalops (as I infer from examinations of alcoholic specimens) does not, I think, invalidate the above conclusion.

Of the two grooves seen on the second segment of the crab's leg it is the proximal one that corresponds to the rupture plane of the lobster's chelæ; the distal one being represented in the lobster by a deep depression, possibly bearing some relation to the exopodite.